

# Antenna Modeling in Software

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# Why Model an Antenna?

- It's very difficult to assemble, adjust, modify, and optimize a physical antenna.
- It's very difficult or time consuming to measure the gain, pattern, and efficiency of a real antenna.
- Antenna models can tell us about efficiency, pattern, gain, and input impedance.
- It's FAST. We can iterate through a lot of models and quickly focus on those that are most useful.
  - Properly done, it's quite accurate.
  - **Improperly done, it can generate complete nonsense.**

# Where does it come from?

- Original software was called BRACT, superseded by Antenna Modeling Program (AMP), developed 1971.
- Numerical Electromagnetics Code (NEC-2) developed at Lawrence Livermore Lab – 1981.
  - Sponsored by Naval Ocean Systems Center.
  - FORTRAN source code is in the public domain.
- NEC-4 also developed at LLL.
  - Not in the public domain. Requires a license from LLL. \$250.

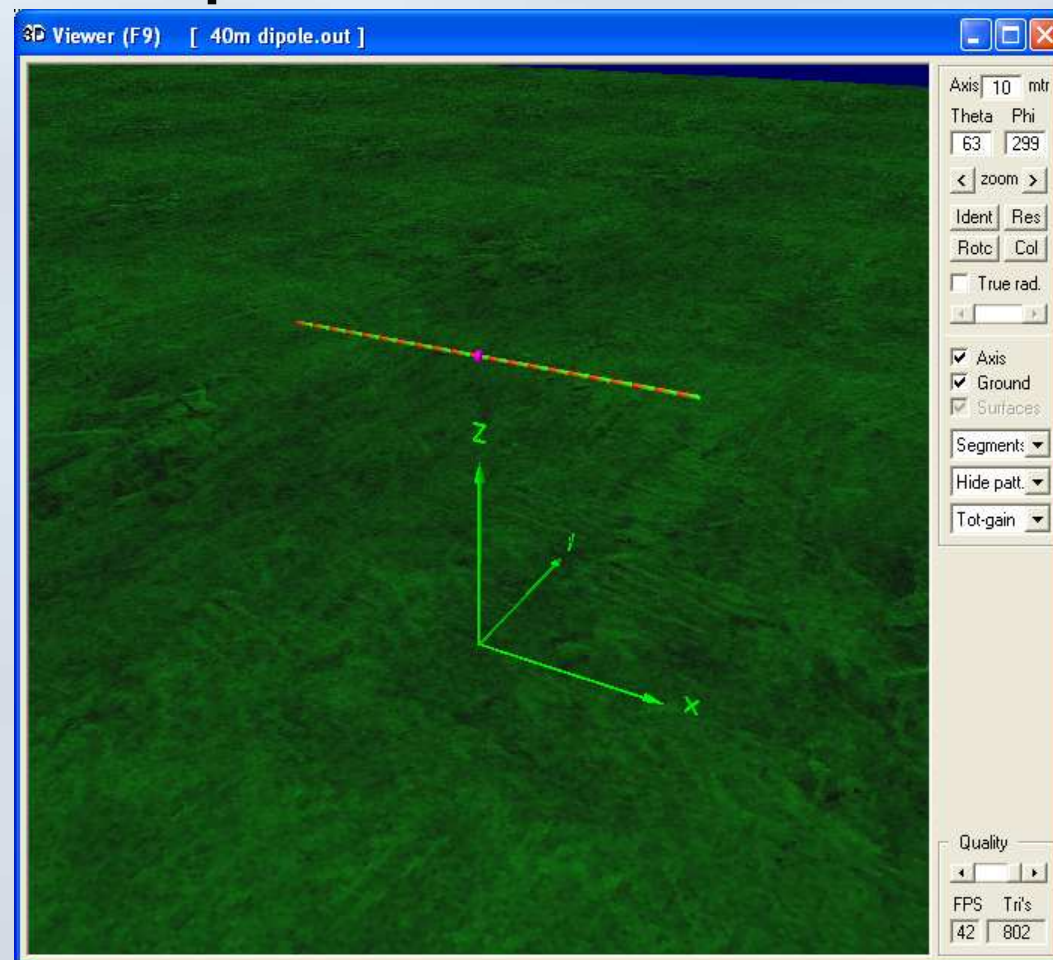
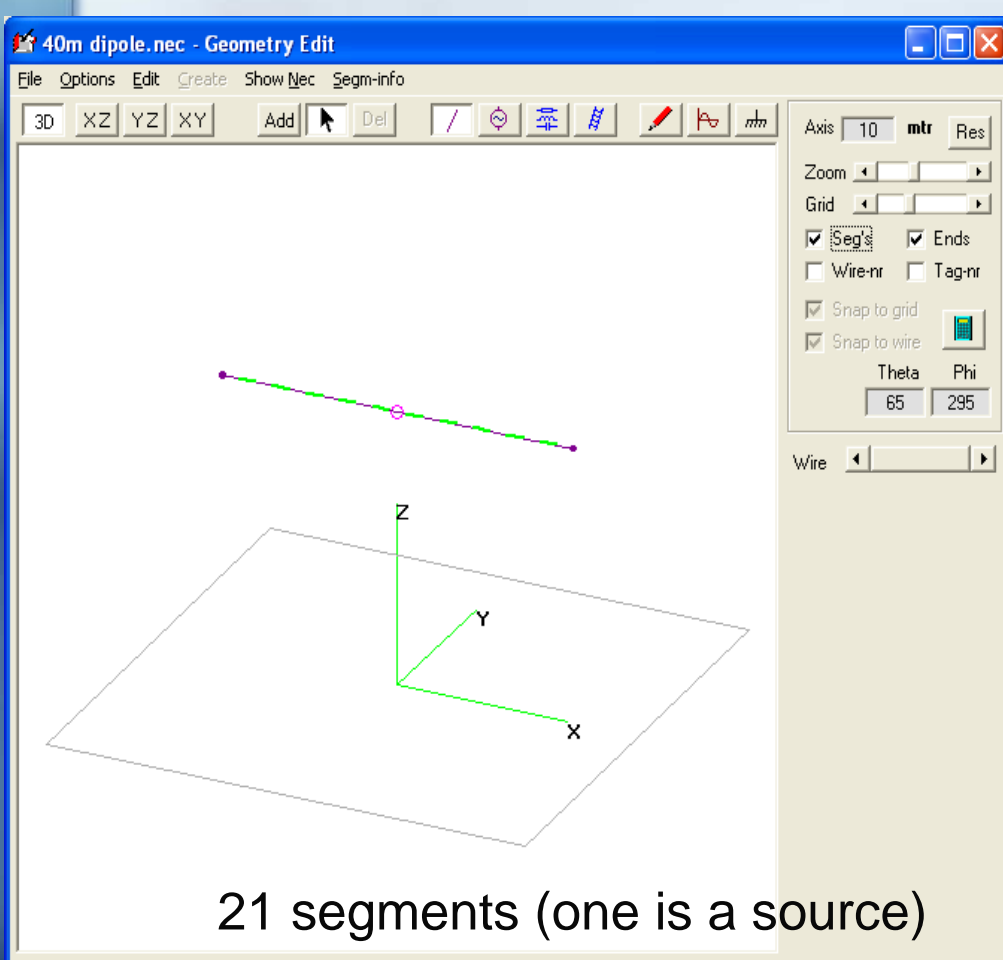
# How does it work?

- Wire antennas are modeled using Electric-Field Integral Equation (EFIE).
- Antenna is broken up into small pieces called *segments*.
- Each segment has current in it
  - Due to sources feeding power to the antenna, plus
  - Currents induced by an impinging field from neighboring segments (and possibly external sources).
- Current in each segment causes radiation.
- The antenna pattern is the sum of all the fields contributed by each segment of the antenna.

# Coordinates

Rectangular (data entry) and Polar (pattern plots)

- Z = up/down X = left/right Y = front/back
- Theta  $\theta$  = elevation, Phi  $\varphi$  = azimuth

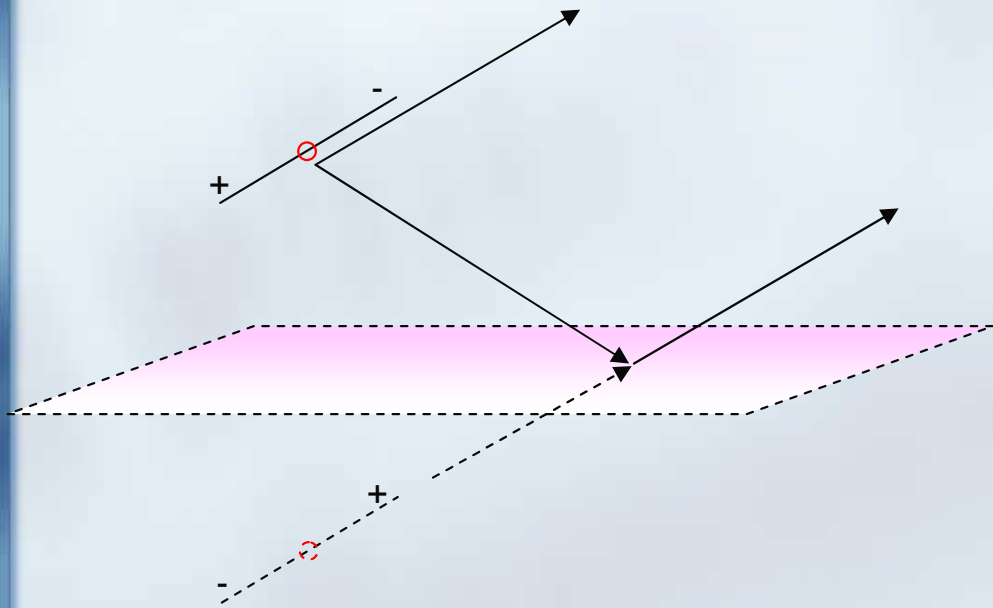


# Ground

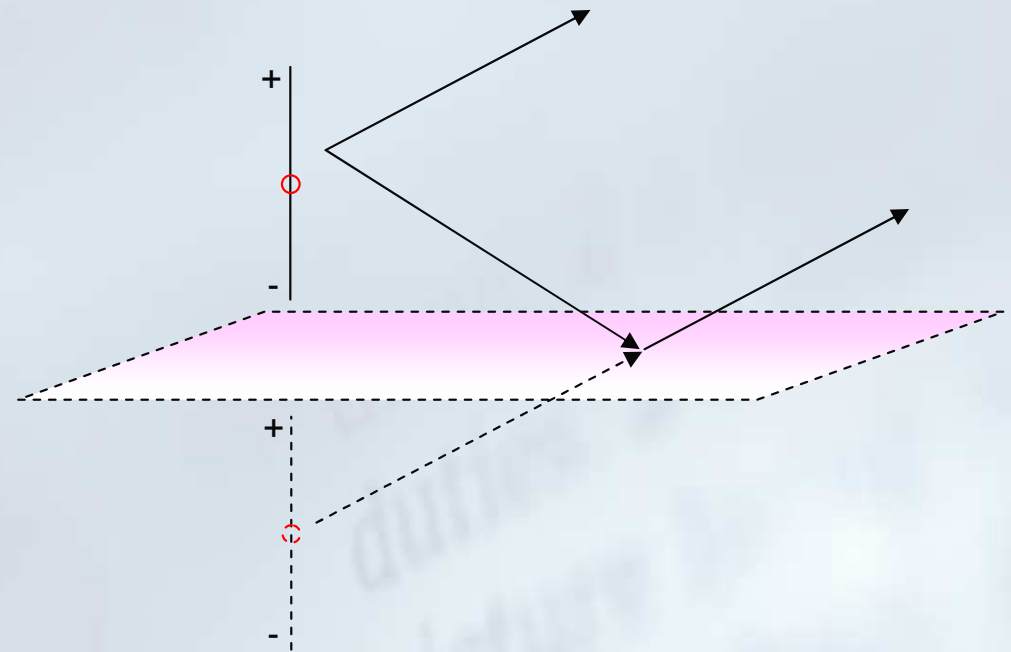
- Ground affects the antenna in 3 ways:
  1. Modifying the currents in the segments due to near-field interaction,
  2. Changing the field illuminating the antenna,
  3. Changing the reradiated field.
- Perfect ground is a perfectly-conducting sheet at  $Z=0$  extending to infinity in all directions (don't we wish).
- The NEC-2 real ground (Norton-Sommerfeld), a lossy sheet of zero-thickness at  $Z=0$  extending to infinity in all directions.
  - Accurate down to about 0.001 wavelengths above ground. The antenna is *not allowed* to touch the ground sheet.
- NEC-4 can model ground with actual depth below ground.
- Computationally, ground is handled by projecting an *image* antenna below ground. Quicker to compute, reasonably good accuracy.

# Image antenna

Modeling with simplified ground



Horizontal Polarization  
and Image



Vertical Polarization  
and Image

# Software

- NEC-2 is free. It's difficult to use.
- Interface software provides a user-friendly interface to NEC-2.
  - Capture / Edit the antenna geometry, loads, and sources.
  - Display the antenna pattern, input impedance, antenna efficiency. Frequency sweeps.
  - Allow selecting loads, sources, wire size, etc.
  - Optimization.
- Most newer interface programs also work with NEC-4.



# Software

## ■ Free

- 4NEC2 (standard) and 4NEC2X (adds 3D visualization). My tool of choice.

- <http://home.ict.nl/~arivoors/>

- MMANA (uses MiniNec rather than NEC-2).

- <http://mmhamsoft.amateur-radio.ca/mmana/index.htm>

## ■ Not Free

- EZNEC - <http://www.eznec.com/>

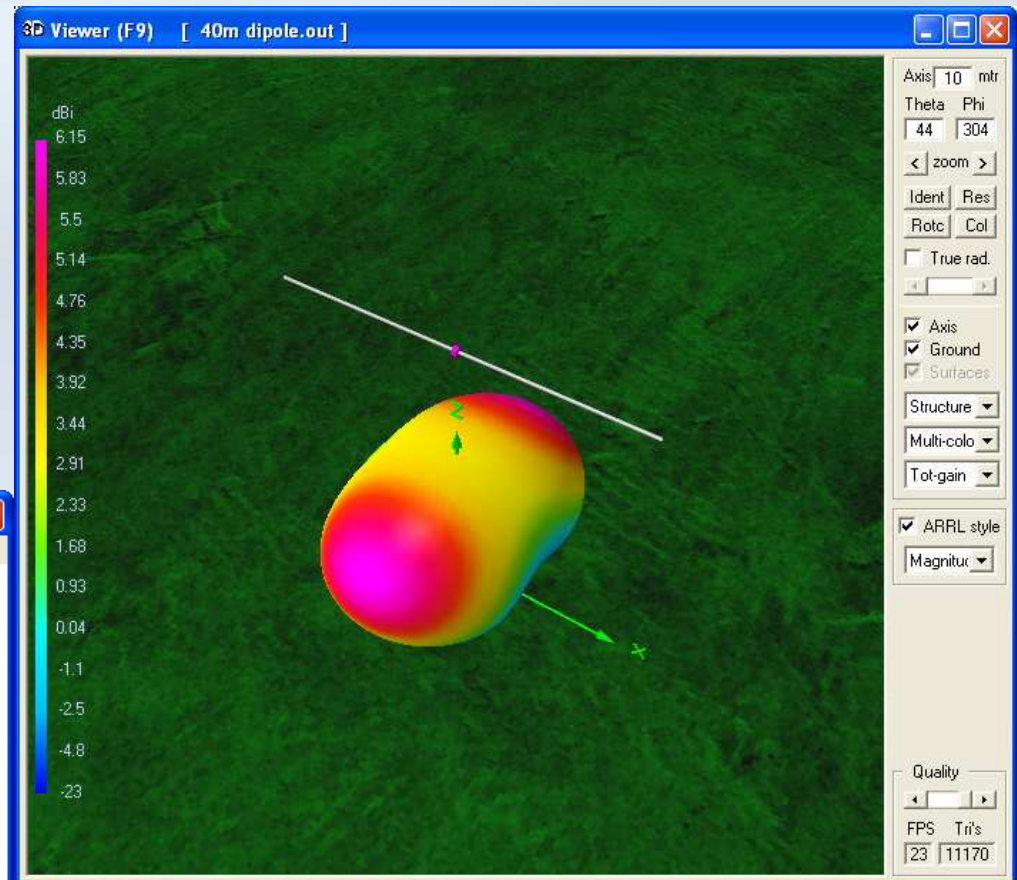
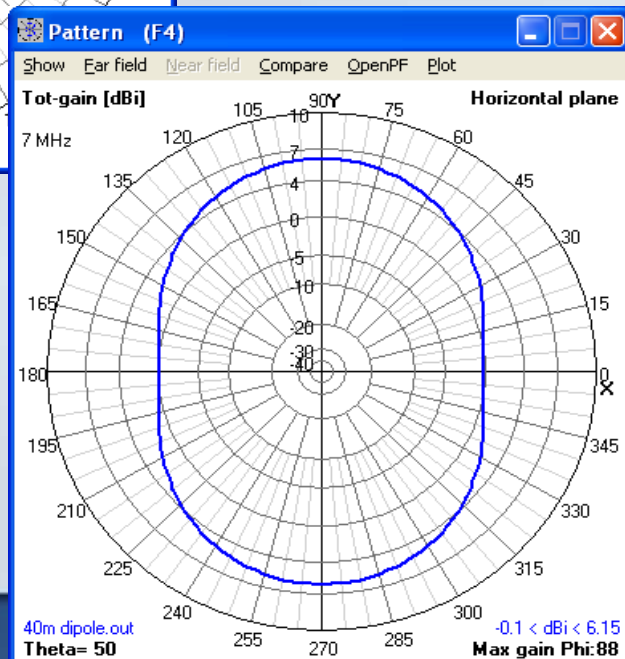
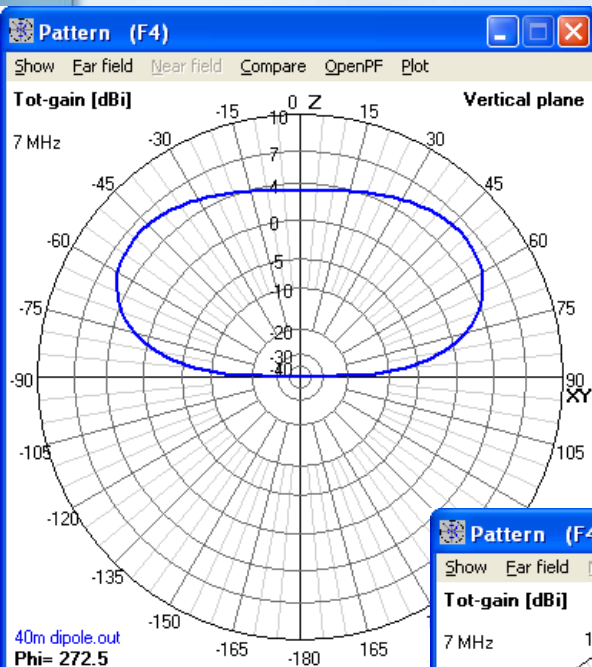
- NEC4WIN - <http://www.orionmicro.com/>

- NEC – Win - <http://www.nittany-scientific.com/>

# Pattern

Polar Coordinates

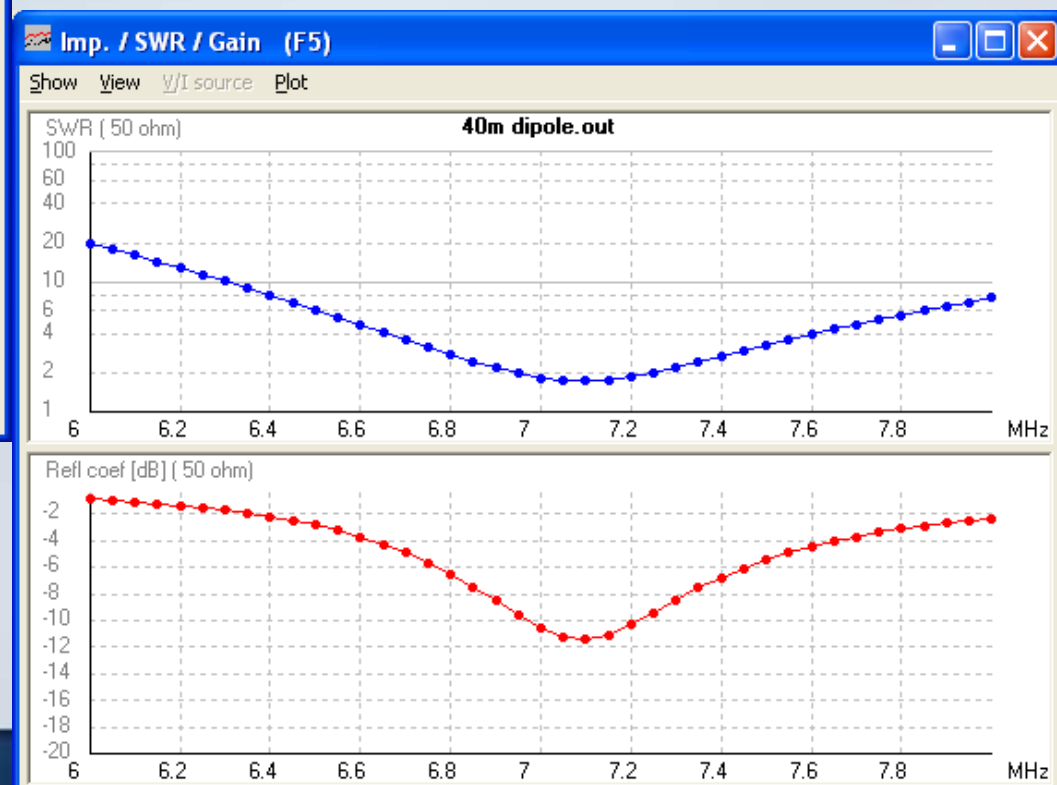
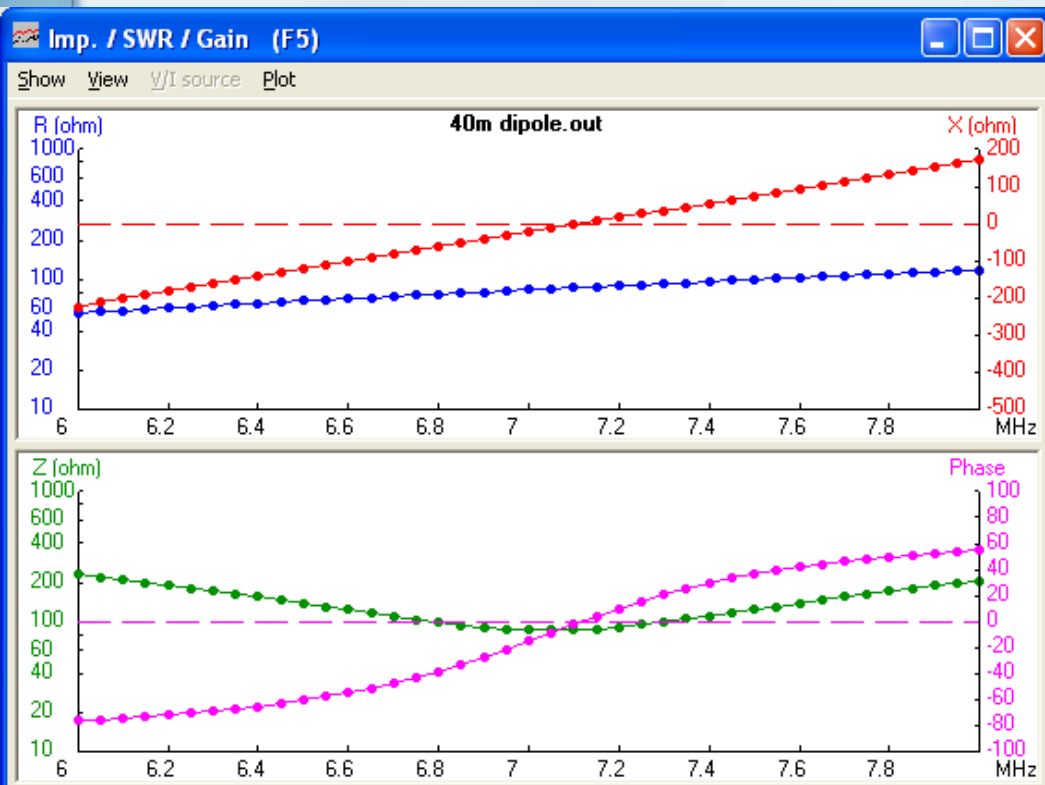
## ■ Azimuth & Elevation or 3D



# Frequency Sweep

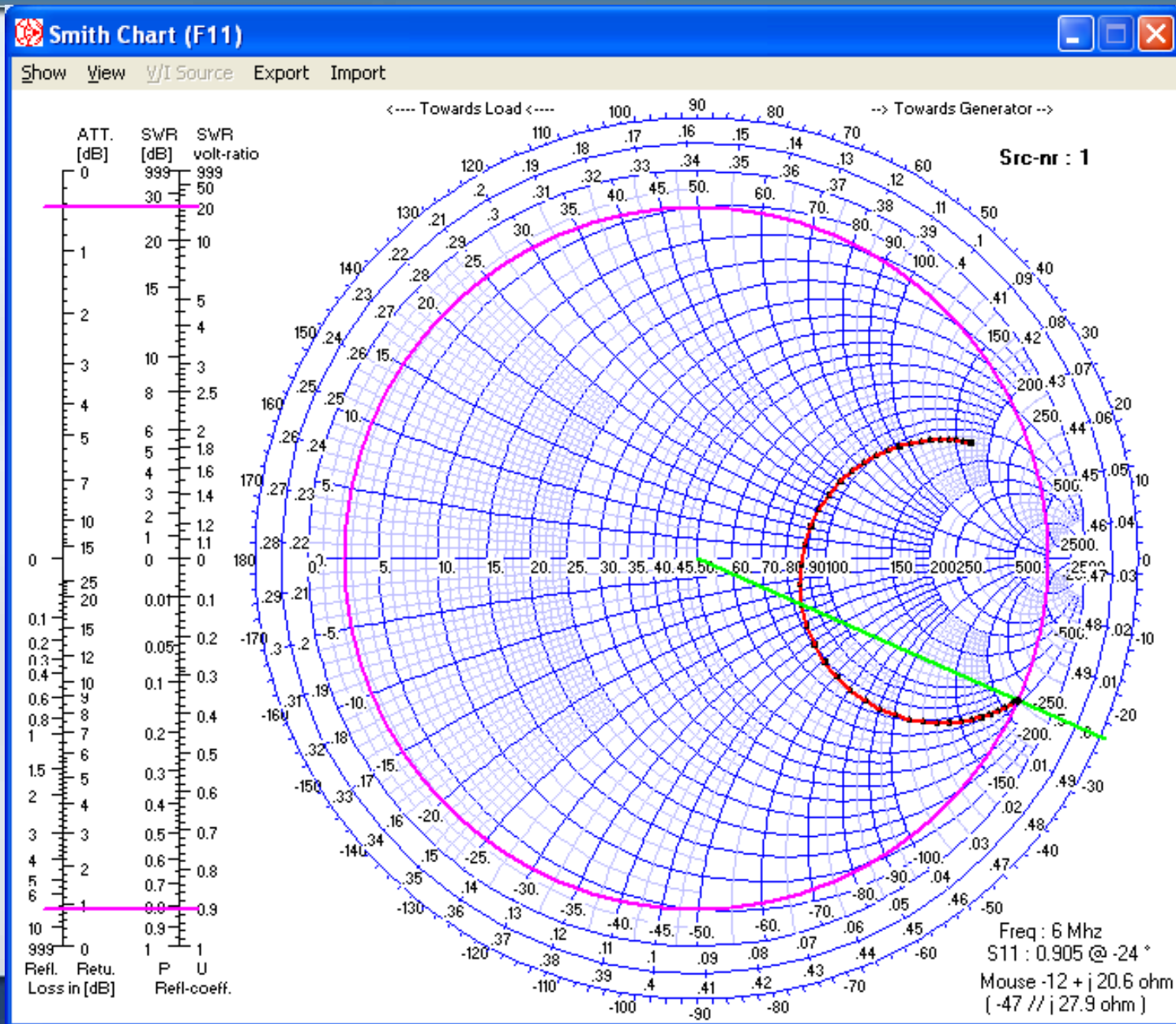
Various ways to show  $Z_{in}$

## ■ $Z_{in}$ , SWR, return loss vs. Frequency



# Frequency Sweep

Smith Chart display of  $Z_{in}$



# Efficiency & Matching

- Efficiency is the antenna itself.
- Radiat-eff includes ground losses.

**Main [V5.7.5] (F2)**

File Edit Settings Calculate Window Show Run Help

Filename: 40m dipole.out    Frequency: 7 Mhz  
Wavelength: 42.83 mtr

Voltage: 94.5 + j0 V    Current: 1.06 + j0.28 A

Impedance: 83.4 - j22.2    Series comp.: 0.504 uH  
Parallel form: 89.3 // -j336    Parallel comp.: 7.646 uH

S.W.R. 50: 1.84    Input power: 100 W  
Efficiency: 100 %    Structure loss: 0 W  
Radiat-eff.: 80.41 %    Network loss: 0 W  
RDF [dB]: 7.1    Radiat-power: 100 W

Environment  
FINITE GROUND, SOMMERFELD SOLUTION  
RELATIVE DIELECTRIC CONST.= 13.000  
CONDUCTIVITY= 5.000E-03 MHOS/METER

Comment  
Blank Empty file for 4NEC2  
\*.Out loading-time=0.313

Seg's/patches	21	start	stop	count	step
Pattern lines	10585	Theta	-90	90	73
Phi	0	360	145	2.5	
Calculation time	1.438 s				

**RLC Matching (F10)**

Z-src (rig): 50    Z-load (antenna): 83.4 - j22    Freq: 7 Mhz

Min netw-Q: 0

Stub match

Q-coil: 250    Q-cap.: 1000

Select network: [none]

Use Network

Exit

NT parameters  
Y11  
Y12  
Y22

**L-network**    q' 0.89

Low-pass	High-pass
1.01 uH    Xs	513 pF
158 pF    Xp	1.76 uH

**Pi-network**    Q 0.9

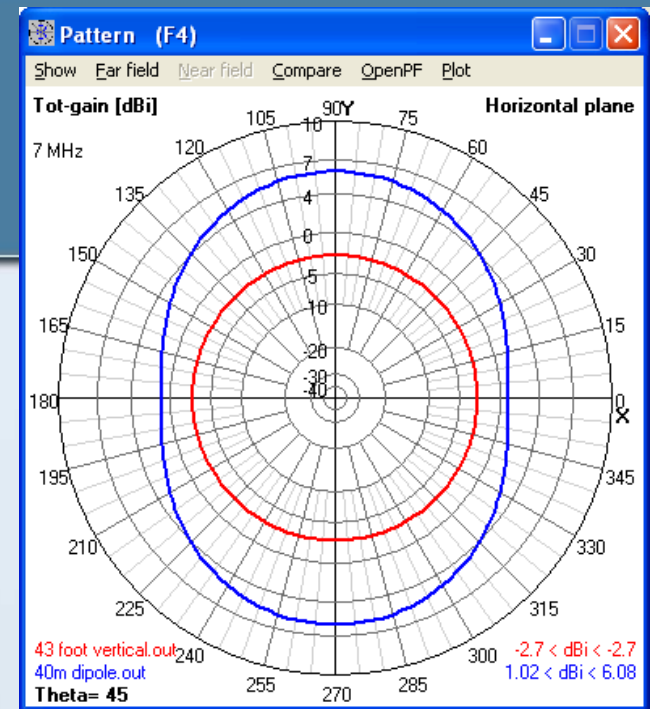
Low-pass	High-pass
42.8 pF    Xp1	12.1 uH
1.12 uH    Xs	463 pF
160 pF    Xp2	1.75 uH

**T-network**    Q 0.9

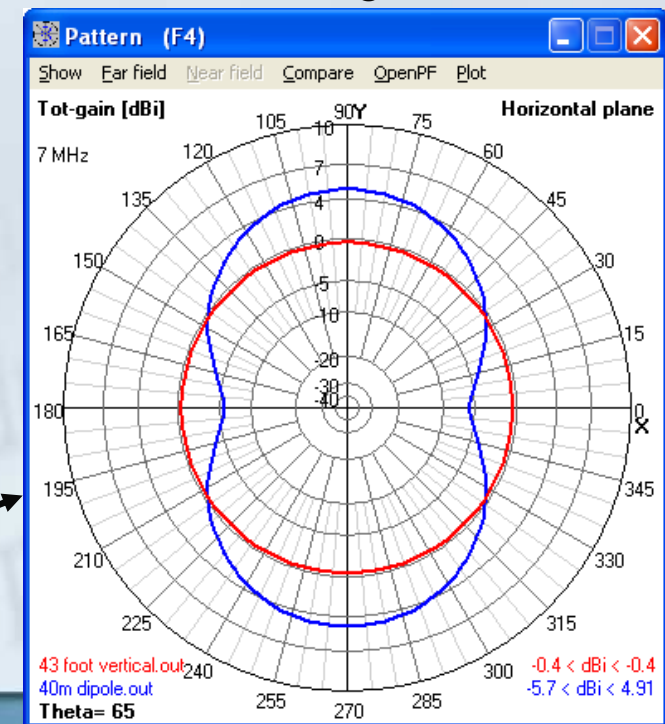
Low-pass	High-pass
1.02 uH    Xs1	508 pF
297 pF    Xp	1.74 uH
1.04 uH    Xs2	15.8 nF

# Comparing Antennas

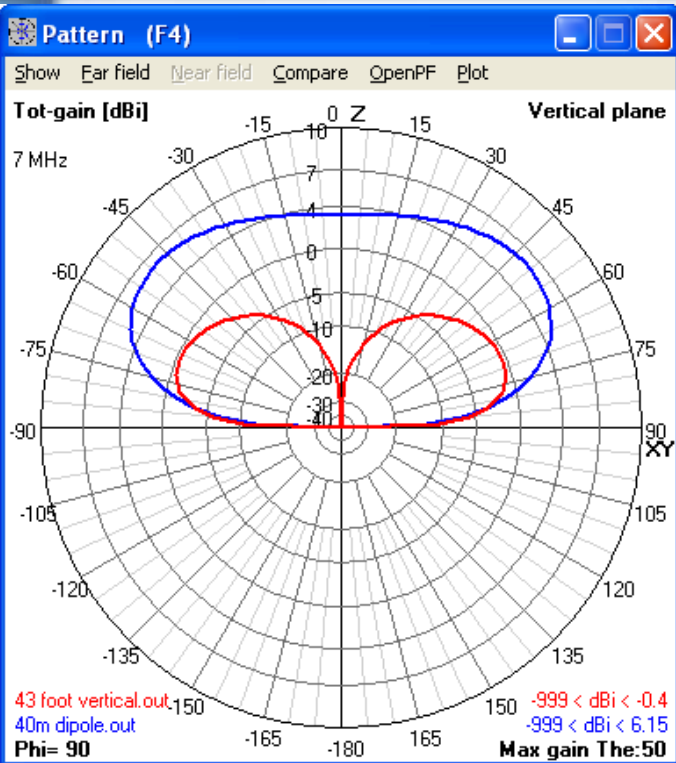
40m dipole at 49 feet vs. 43 foot vertical+32 radials  
 Real Ground "good"



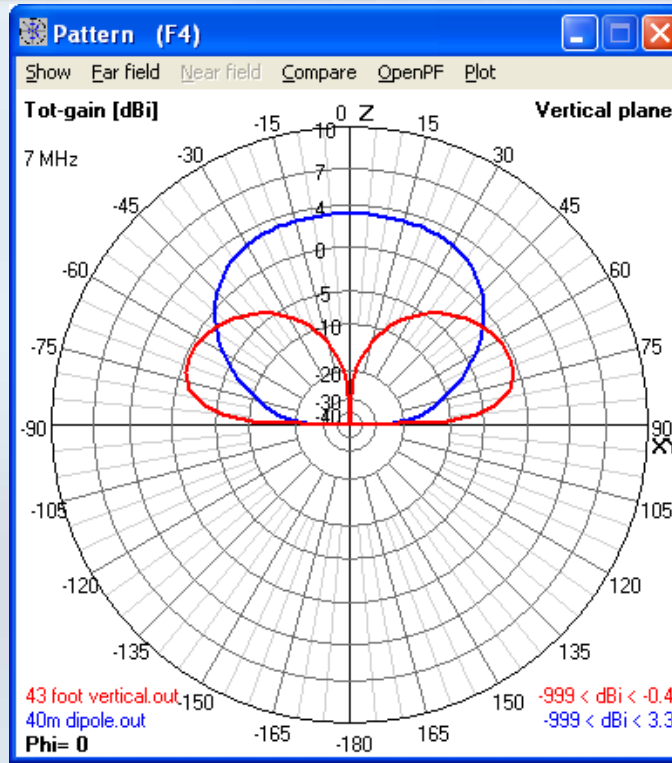
At 45-degree elevation



At 25-degree elevation  
 (best angle for vertical)



Broadside to Dipole



End of Dipole